Real-Time System Operations using Synchrophasors

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Overview

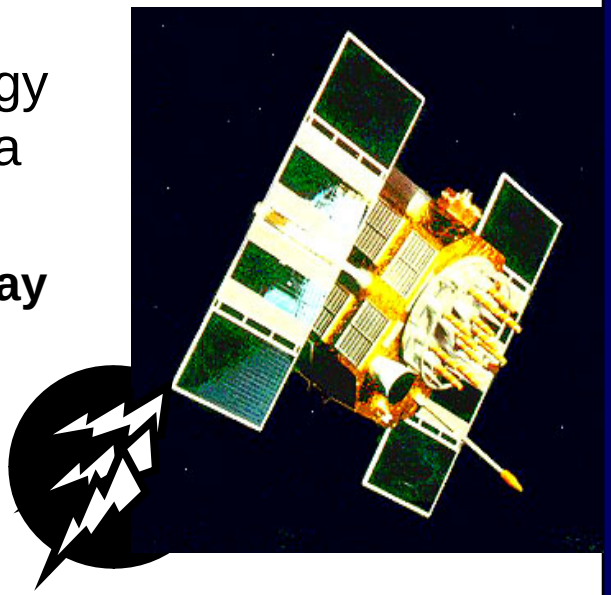
- **CERTS has worked closely with CAISO on phasor technology research in support of real-time system operations. This effort has been led by with Manu Parashar, Electric Power Group**
- **Today's Presentation covers:**
  - **Context for phasor technology research**
  - **Present phasor research completed including implementation of the Phasor-RTDMS in CAISO control room with 13 clients**
  - **Introduce proposed research for the 2008 to 2010 time frame**
  - **Present new research concepts for consideration to utilize smart grid and phasor technologies for renewables integration**

Context for Phasor Technology Research

- **What is Phasor Technology?**
- **How does Phasor Technology relate to current SCADA technology?**
- **What are the research building blocks?**
- **What has been accomplished so far?**
- **What research is planned and why?**
- **How does this research leverage other initiatives?**

What is Phasor Technology? – Key for the Grid of The Future

- **Phasor Measurement Units – Mature Hardware, Emerging Networks and Applications**
  - Supplements 50-year old SCADA technology
  - GPS time synchronized high resolution data
  - Wide coverage
- **Provides MRI of Power System Compared to X-ray Quality Visibility From Traditional SCADA**
  - Wide-area situational awareness
  - System dynamics monitoring
  - Improved modeling
- **Addresses Current Industry Problems**
  - Blackout prevention and mitigation
  - Congestion and bottlenecks
  - Visualization – wide area, common data, common displays
  - Security Assessment – safe operating zones
  - *Renewables Integration*



Phasor vs. SCADA Measurements

ATTRIBUTE	SCADA	PHASORS
Resolution	1 sample every 2-4 seconds	10-60 samples per second
Measured Quantities	Magnitude Only	Magnitude & Phase Angle
Time Synchronization	No	Yes
Focus	Control Area (Local) monitoring & control	Wide area (interconnection) monitoring & control
Observability	Steady state only	Steady state, dynamic and transients
Monitoring Angles, Damping, Frequency Response, & Other Metrics	No	Yes
Oscillation Detection	No	Yes

Phasor technology is *NOT* a replacement for SCADA, rather it *complements* existing SCADA systems

Evolution of Phasor Technology Research

Hardware R&D

- PMUs
- PDCs
- DFRs

70's - 90's

Local Data Collection & Post-Event Analysis

- BPA
- SCE
- AEP
- PG&E
- NYPA
- ALBERTA

90's-2000

Starter Phasor Network – Local and Wide Area Data Networking and Monitoring

- WECC – CAISO, BPA, SCE, PG&E, WAPA
- EIPP
- NASPI

2000-2010

Phasor-Based Real-Time Applications - Research, Demonstrate, Field Trials, User Acceptance

- Visualization
- Operator Dashboards
- Monitoring
- Alarming
- State Estimation System Dynamics
- Control/Protection

2005

Phasor – RTDMS Platform

- **RTDMS is a phasor application platform that translates research concepts to applications for use by operators, reliability coordinators, and operating engineers**
- **The first prototype application was tested in 2003 - currently in use at CAISO, BPA, TVA, WECC Utilities and other NASPI participants.**
- **RTDMS platform comprises of: (1) Data Management Hub; (2) Database; (3) Web Services for Reports and Data Retrieval, and (4) Client Applications for wide-area visualization, dashboards to diagnose health of the grid, event analysis and small signal stability.**
- **CERTS research focused on key metrics and prototypes for implementation on RTDMS platform**
  - **Grid Stress – phase angle measurements**
  - **Grid Robustness – detecting damping status and trend**
  - **Dangerous Oscillations – implementing algorithms for oscillation detection and alarming**
  - **Frequency Instability – Frequency variation across interconnection**
  - **Voltage Instability – Identify Low Voltage Zones, determining reactive margins and linking to operator actions**
  - **Reliability Margin – "How far are we from the edge" – Sensitivity metrics**

WECC WAMS & Integration with CAISO PDC

54 PMUs integrated across four organizations via WECC WON

PMU Inventory:

BPA – 23

WAPA – 4

LADWP – 1

SCE – 18

PG&E – 6

SRP/APS – 8

BC Hydro – 11

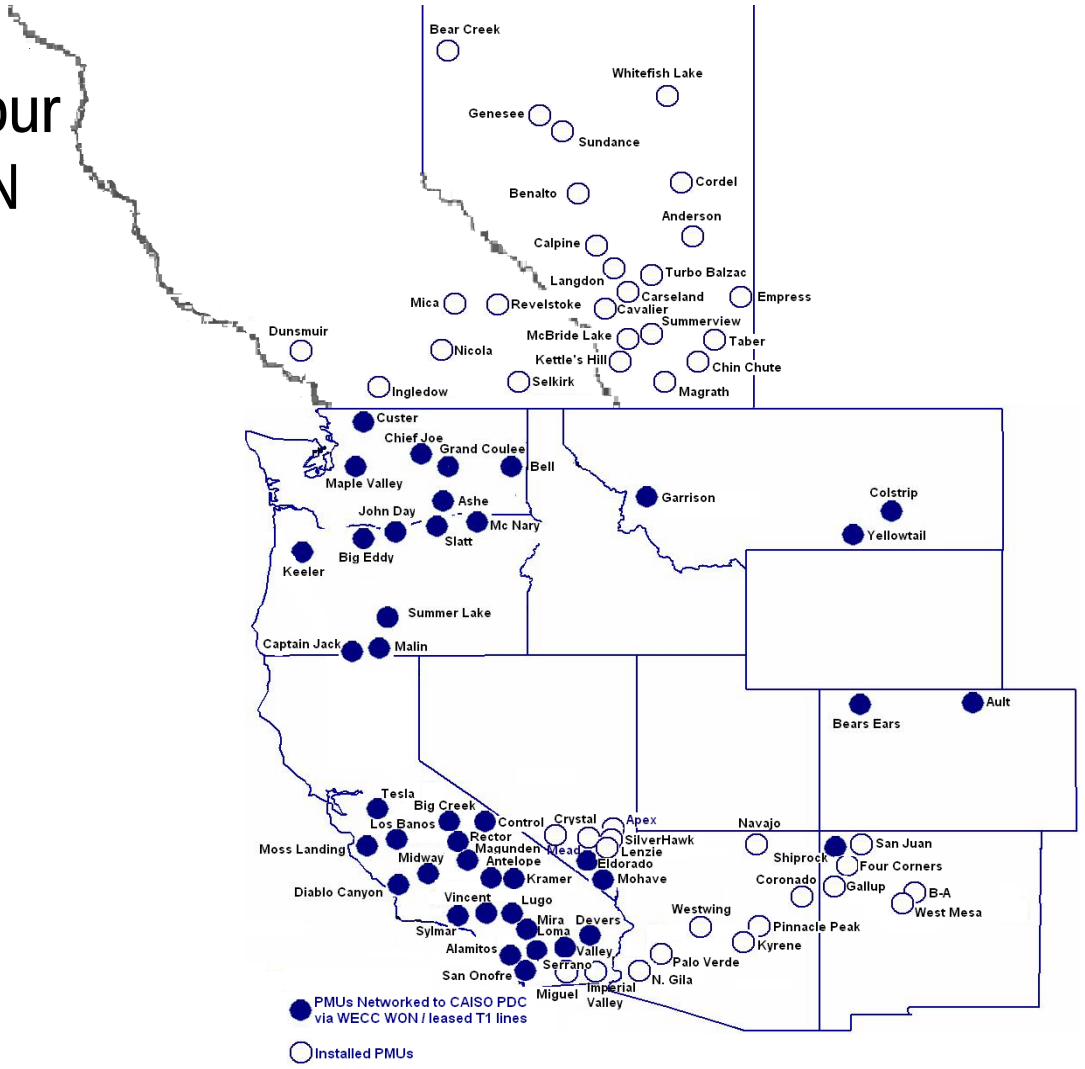
PNM – 4

SDG&E – 5

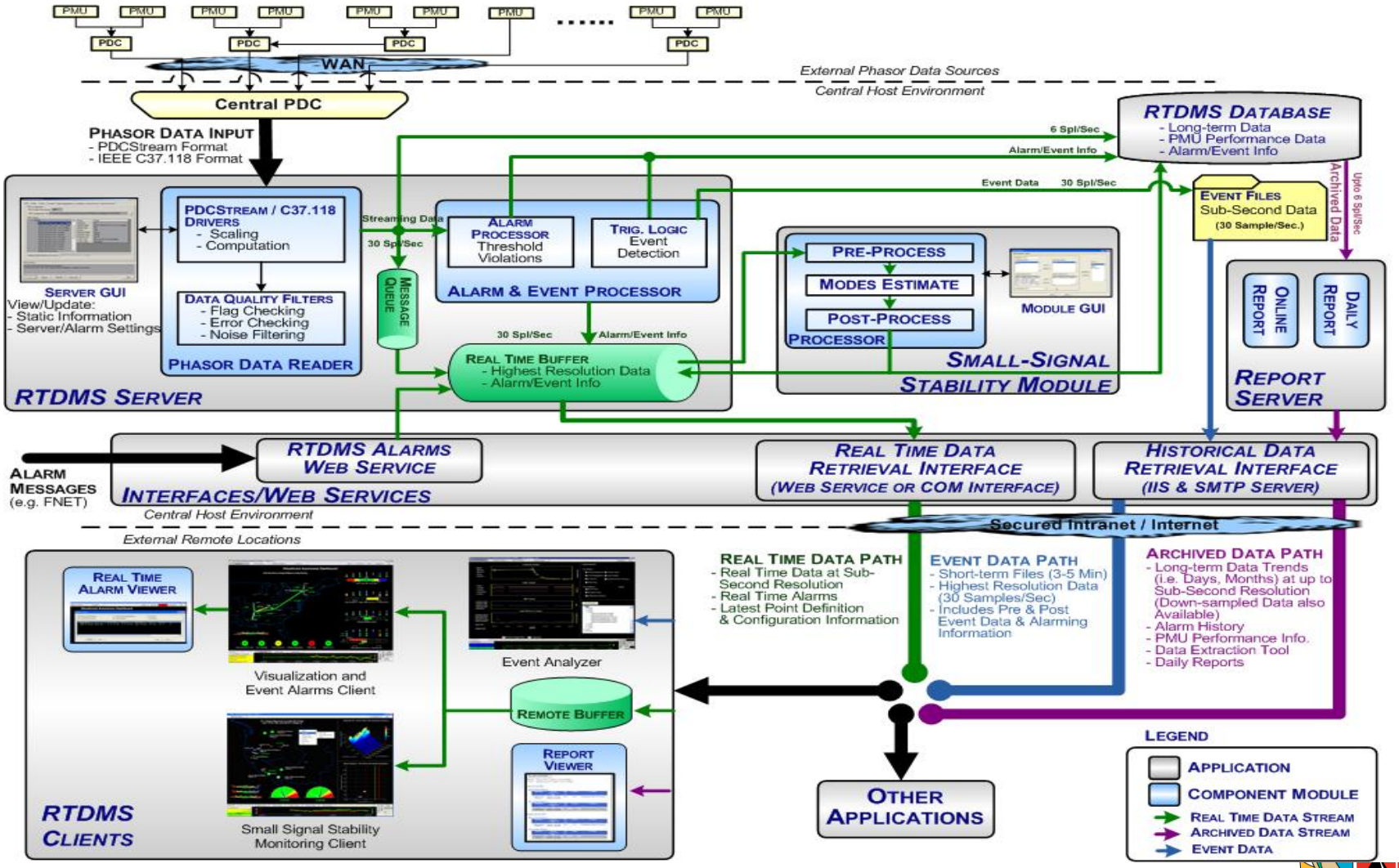
AESO – 26

NPC – 6

Total: 112



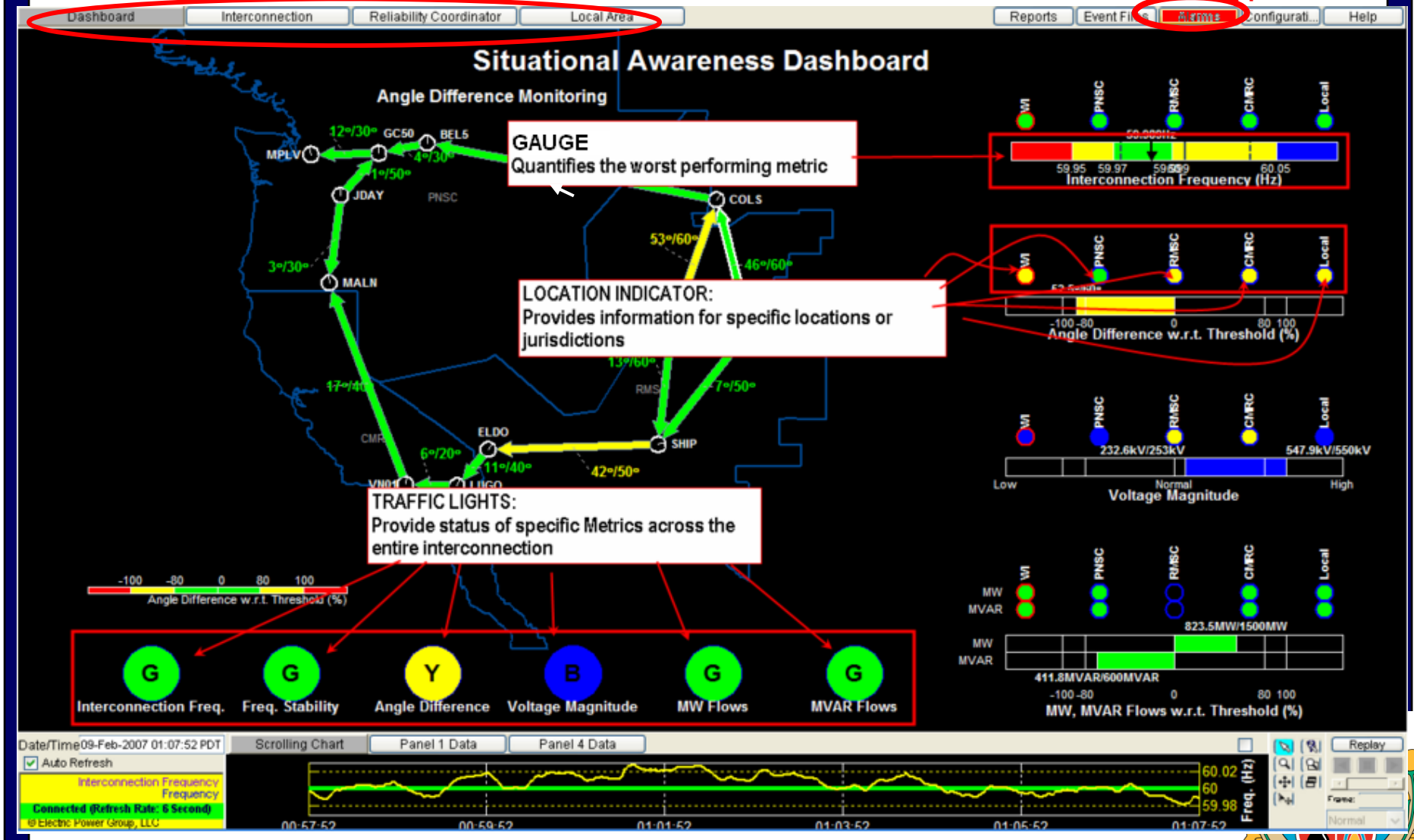
CAISO Phasor System Architecture
– RTDMS is an Open Platform for Phasor Research



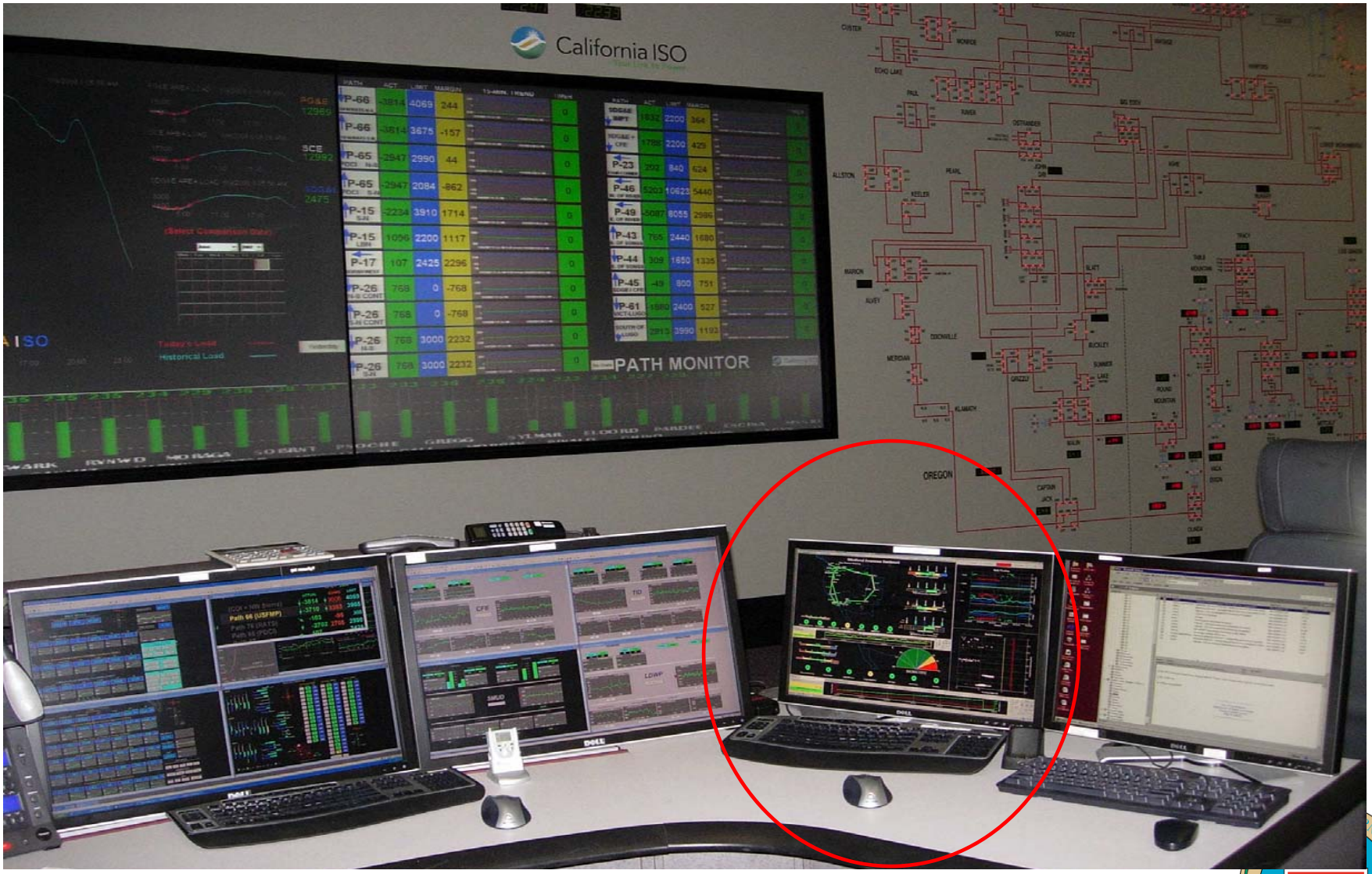
Visualization – In Use at CAISO

Visualization Tiers – Dashboard, Interconnection, Reliability Coordinator, Local Area

Real Time Alarms within ALL RTDMS Client Applications



Visualization – In Use at CAISO

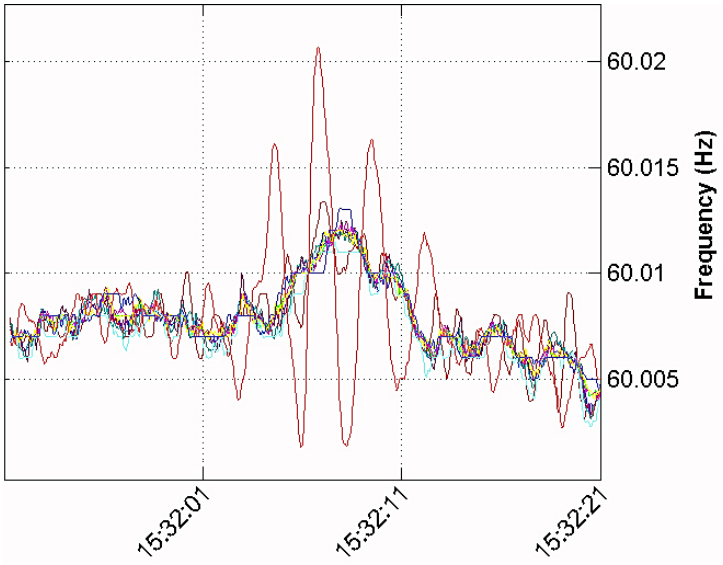


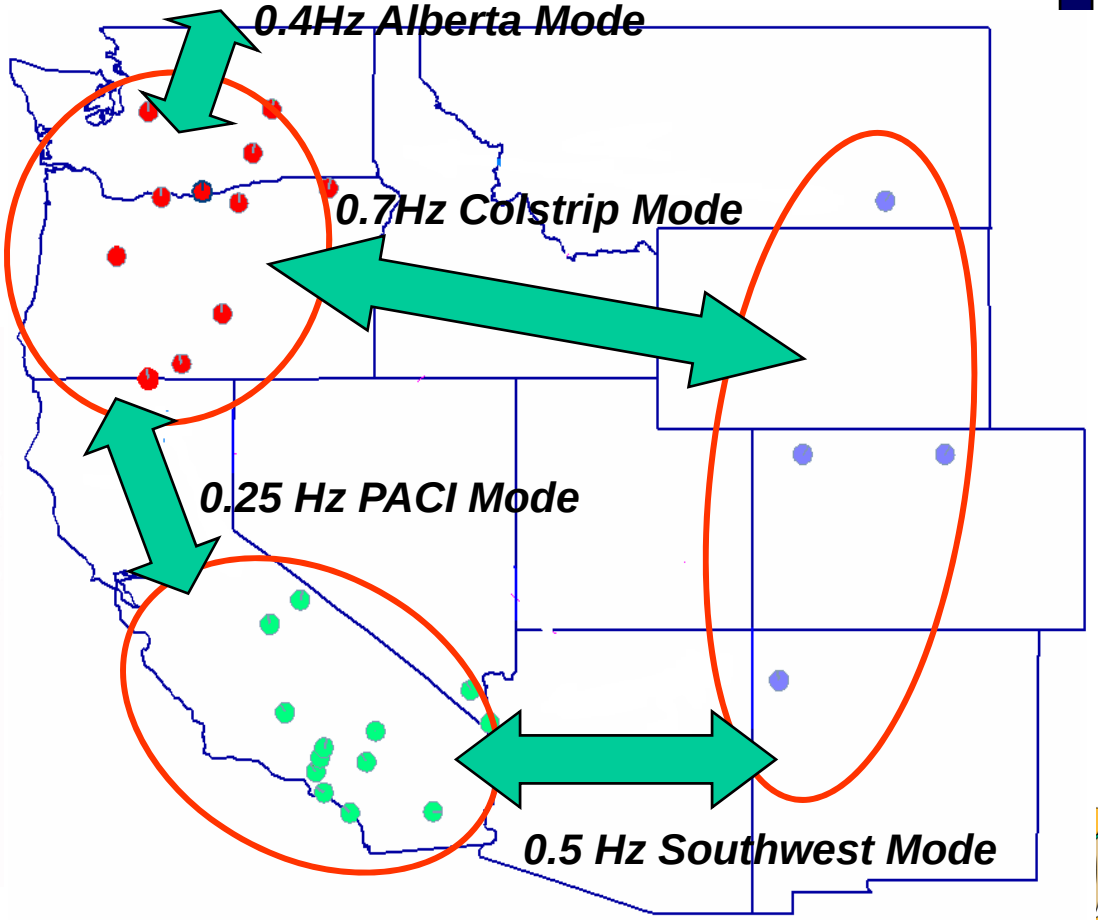
Small Signal Stability is an Emerging Focus – Mode Identification and Characterization

Goal: ***Real-time*** identification of oscillatory modes from ***ambient*** phasor data

Higher Damping ⇔

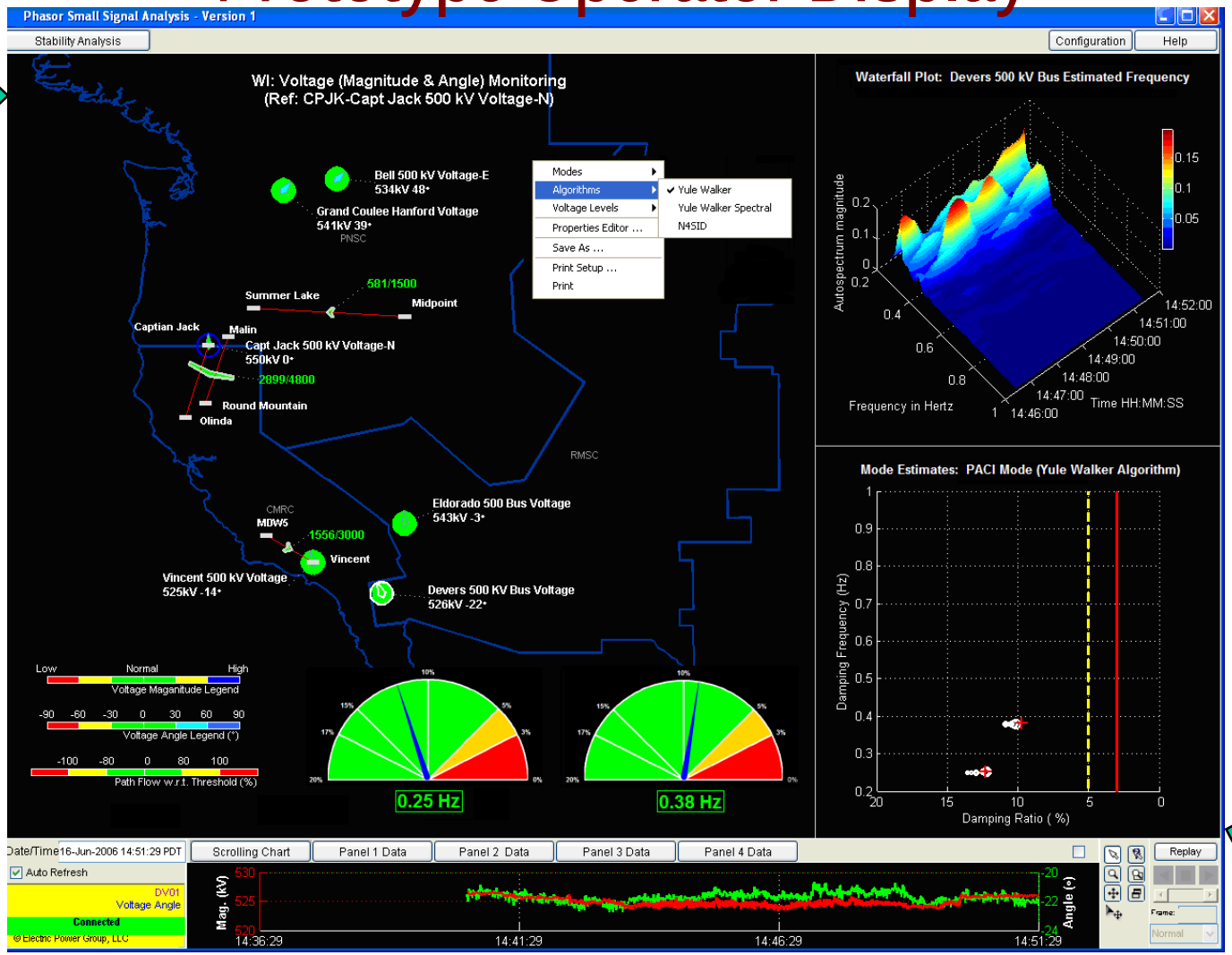
Greater Stability





Stability Monitoring – Small Signal Stability – Prototype Operator Display

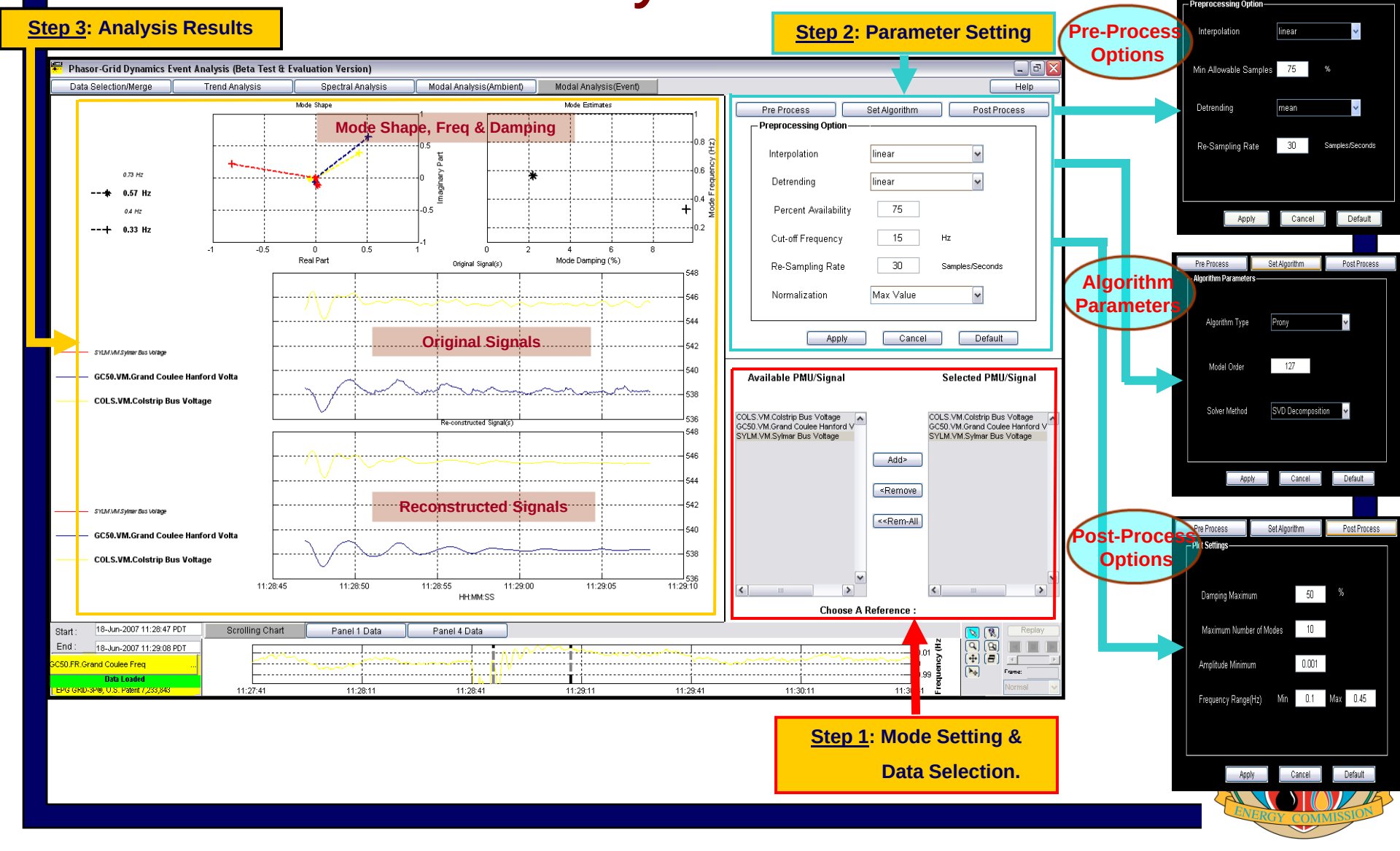
Monitor : Low Frequency oscillatory modes across the interconnection



Waterfall to identify oscillation freq. and it's trend over time

Frequency-damping plots to track % damping of different oscillatory modes in real time (3% and 5% alerting and alarming thresholds shown)

Offline Analysis – Phasor Grid Dynamics Analyzer Tool



Phasor Technology Research Framework

Infrastructure – CAISO, Utilities, Vendors

Data Mgmt Research

Operator Applications – Data Utilization Research

Planning & Asset Management Applications Research

MEASUREMENT PMUs

4 Local Data Collection – Manual Retrieval

Data Concentration PDCs

4 Real Time Streaming Data to Control Centers

Local Networks – Utility

4 Hub and Spoke Architecture

Wide Area Network - CAISO/WECC

4 Distributed Network

2 Data Coverage

- 52 PMUs
- Need Coverage – BC, AZ, R/M, CO, NV, Baja

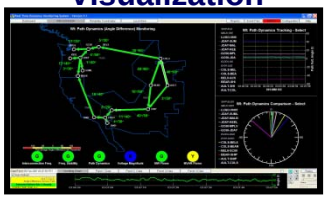
1 Data Quality

- Validation
- Reliability
- Redundancy

1 Data Management

RTDMS Server – Collection, Archiving, Retrieval

1 Dashboard Visualization



2 3 Monitoring Metrics & Thresholds

- Grid Stress
- Robustness
- Oscillations
- Reliability Margin
- Phase Angles
- Damping
- Modal Energy
- Reactive Reserves
- Sensitivities

3 Alerts & Alarms

- E-Mails, Alerts, Alarms
- Soft Limits
- Hard Engrg. Limits
- Statistical & Pattern Limits

3 Operator Actions Decision Tools

- Manual
- Automatic
- Stability Nomograms

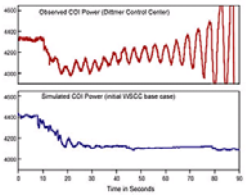
2 Event Analyzer

- Root Cause
- Forensics
- Standards

2 State Estimation

- Phasor Data
- Integration with State Estimator
- Results Evaluation

4 Planning Models Validation



4 Grid Upgrades

- Voltage Support
- Flow Control
- Bottlenecks

1 Completed

2 Partially Completed

3 Planned 2008 to 2010

4 Industry funded or other sponsors

What Research is Planned and Why

a. **Visualization Dashboard – expand coverage for full visibility of WECC Monitoring Metrics and Thresholds – Real Time**

b. **Operators can see data. Key issues: What are the key Metrics? What actions should operators take?**

c. **Research and analysis of metrics**
   - **Grid Stress – Phase Angles**
   - **Robustness – Damping**
   - **Oscillations – Modal Energy**
   - **Reliability Margin**

d. **Alerts, Alarms – How do operators know when to act and what actions to take?**
   - **E-mail notifications**
   - **Root cause diagnostic**
   - **Alert and alarms linked to metrics**
   - **Decision tools**

e. **Oscillatory Modes – Small Signal Stability**
   - **What are they, What are the precursors, What is normal vs. abnormal?**
     - **Algorithmic research**
     - **Monitoring approach under system normal and abnormal conditions**
     - **Operator actions, alerts**

f. **Critical Path Monitoring and Nomograms**
   - **Research and analysis for Intertie operation, nomograms, RAS**

g. **Voltage Stability**
   - **Research based on phasor measurement based voltage stability analysis (reactive margin, voltage sensitivity) to advance state of art of current model and simulation based assessment**

h. **Integration of Renewables and Dynamic Impacts**
   - **Research and analysis for renewables integration (wind – no governor or frequency response) and impact on system dynamics and oscillatory behavior**

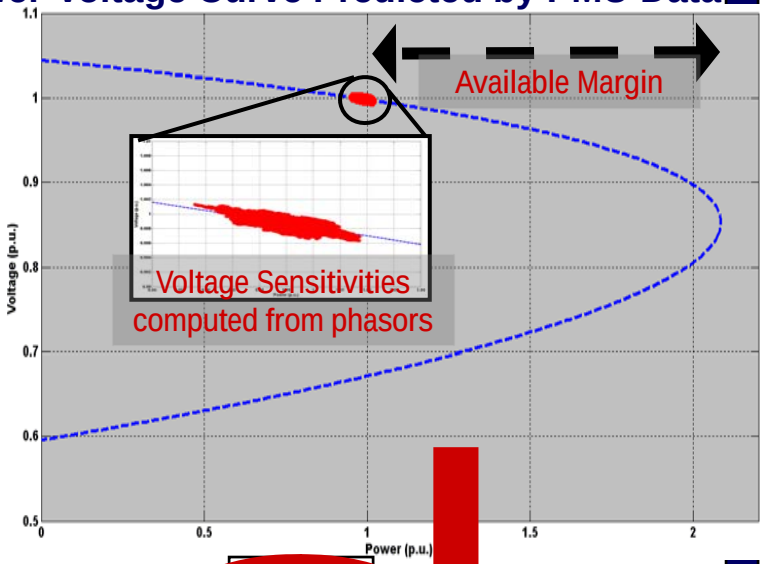
i. **Platform and Infrastructure – What is needed for system-wide coverage & data exchange?**
   - **Architecture**
   - **EMS Integration**
   - **Research Roadmap**

Expected Research Results – Translate Concept to Prototypes. Example: Monitor Distance from Edge and Alert Dispatchers

Question: How far are we from the edge?

With PMUs, we can directly measure Voltage Sensitivities (kV/100MW) at critical interfaces/ load pockets AND estimate margins

Power-Voltage Curve Predicted by PMU Data



Higher Transfer Limits

Higher Energy Flows

Voltage Stability

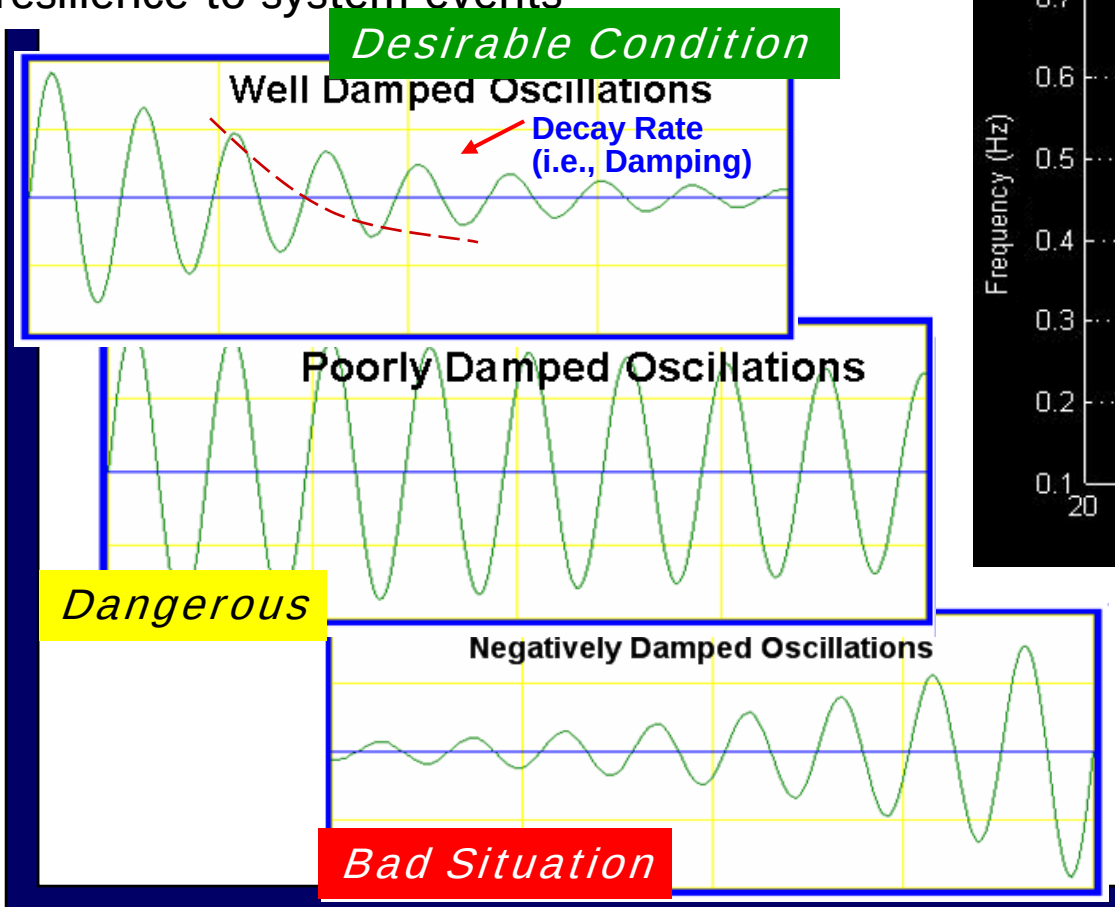
When voltages drop too far, the entire power system can collapse

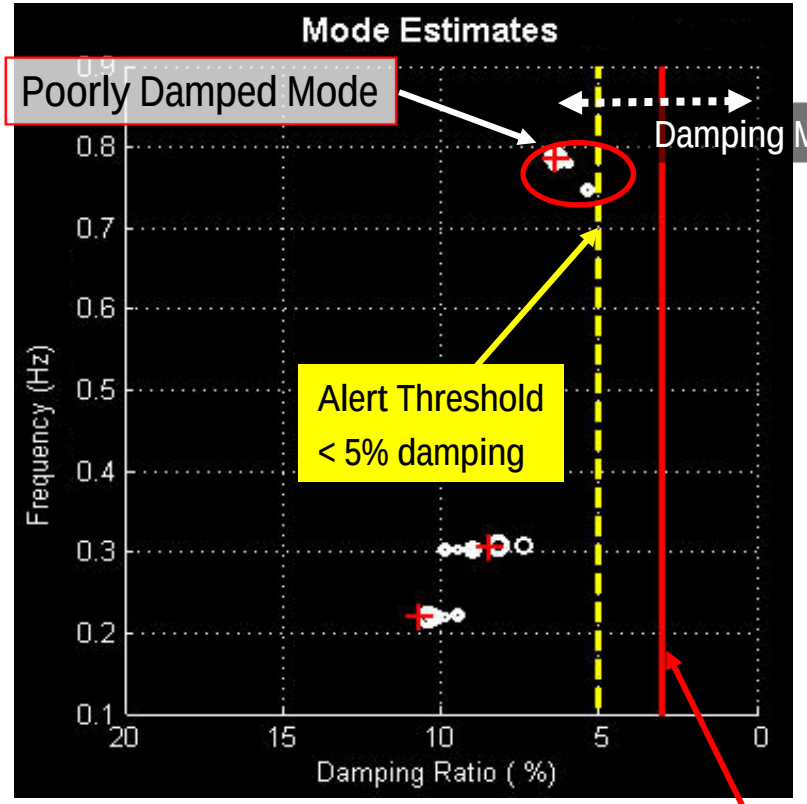
Large power flows over long distances increase the risk of voltage collapse

Expected Research Results – Translate *Concept to Prototype* – Example: Grid Robustness

Question: How well can the system withstand disturbances?

Damping (in %) is a measure of the grid's resilience to system events





Research Leverage – Activities and Linkages With Other Initiatives

- **DOE** – **sponsorship for NASPI, advanced phasor research, and phasor gateway research**
- **CAISO** – **prioritize needs, approve research and applications development plan, continue to serve as a test bed, and provide user feedback**
- **CA IOUs** – **local network infrastructure and applications**
- **WECC** – **adoption of phasors based on CAISO experience**
- **BPA** – **serve as a test bed to validate research approach**
- **Montana Tech** – **algorithmic research on small signal stability to implement on the RTDMS platform**
- **EPG** – **RTDMS development, wide area monitoring applications for CAISO operators, research planning, end-user interface**
- **PNNL** – **research in human factors, research and advanced algorithms**
- **LBNL** – **program and project management**

CEC funded Phasor Research Project has positioned California and CAISO as an industry leader

Phasor Technology – Challenges

Infrastructure Expansion

- Data sharing among California utilities, NERC, WECC RCs, and TOs:
  - ***Institutional challenges*** – Need to overcome data confidentiality concerns – CAISO and NERC working on this issue
  - ***Technical challenges*** – Network design, management and funding
- Expand Network to Close existing Observability Holes – Integrate PMUs belonging to APS, SRP, and BC Hydro into the real time WECC Phasor Network.
- Newly formed WECC Wide Area Measurement Task Force (under OC) is emerging focal point for these activities
- New WECC Reliability Coordinator – outreach and deployment

Applications Migration/Integration/Acceptance

- Identify CA IOU applications that can leverage CAISO platform
- Leverage knowledge being developed and exchanged both nationally and internationally through NASPI

Institutional

- Contracts and funding for researchers without a break

New Research Opportunity

- **Utilization of Smart Grid and Phasor technologies to boost utilization of existing transmission to facilitate renewables integration**
- **Proposed Areas for Research**
  - Current constraints, limiting factors, technology solutions
  - Smart Grid Phasor Applications Feasibility Assessment – dynamic ratings, RAS, SVC Dispatch, Global Voltage monitoring and local control, equipment monitoring
  - Research prototypes, testing, demonstration, field trials, implementation
- **Context:**
  - California needs to integrate 30,000 MW of renewables in next 20-years (CERTS/EPG Study)
  - Transmission is a key enabler for integration
  - Current transmission use is limited by stability constraints – e.g., 20,000 MW transmission gateway capacity in Southern California vs. 10,000 MW ratings; COI thermal capacity of 7,000 MW vs. rating of 4,800 MW
  - New transmission – long lead time, siting issues, expensive

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